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Northernmost recorded breeding of the Black Pennant *Selysiothemis nigra* (Vander Linden, 1825) shows further spread in the Carpathian Basin (Odonata, Libellulidae)

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Abstract

Northward range expansion has become increasingly common among European arthropods in recent decades. As global temperatures rise and the spread of artificial habitats alters ecological conditions, many species are establishing breeding populations outside their native ranges. The Black Pennant *Selysiothemis nigra* (Vander Linden, 1825), considered native to the Iranoeremian region, has shown a rapid range expansion across Europe, reaching several new countries since the 2000s. As part of this process, the species was recorded in Hungary as well as in the Carpathian Basin in 2020 for the first time, when a single female specimen was observed during a field survey. In this study, we examined the species at the northern edge of its current European distribution in Hungary, using both traditional field observations collected between 2020 and 2025 and citizen science data. We documented 39 new occurrences, including multiple swarms consisting of more than one hundred individuals. At one of these sites, where copulating adults had previously been observed, larval sampling revealed the presence of immature stages. A total of 11 naiads were found in two gravel pit lakes, providing direct evidence of successful reproduction at 47.3262°N. This represents the first known autochthonous population in the Carpathian Basin and the northernmost breeding population of the species worldwide. Our results demonstrate that the Black Pennant is established and increasingly widespread in the Carpathian Basin, highlighting the importance of confirmed breeding populations in assessing range dynamics while emphasizing the growing value of citizen science platforms for tracking distributional changes in arthropods.

Key Words

Autochthony, citizen science, dragonfly, range expansion

Introduction

Range expansion is a well-known phenomenon in which species extend their native geographical distribution, often in response to changing environmental conditions such as climate change or human-induced factors (Parmesan and Yohe 2003). Although this expansion may theoretically occur in multiple directions, in Europe, an increasing number of species have been notably shifting northwards in recent decades (Hickling et al. 2006; Thomas 2010; Chen et al. 2011), resulting in the establishment of new populations beyond their historical ranges (e.g. de Boer and Harvey 2020; Anselmo et al. 2023; La Porta and Handersen 2024).

As part of this process, Mediterranean arthropods are increasingly appearing in new, previously unoccupied regions farther from the Mediterranean basin and coastal areas (Hickling et al. 2006; Termaat et al. 2019; Olsen et al. 2022). This trend is particularly pronounced in flying insects such as dragonflies, whose strong dispersal ability enables them to overcome large geographical barriers

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(Olsen et al. 2022). Several studies have documented shifts in the distribution of European dragonflies, indicating a mainly northward movement of species into central and northern Europe (Hickling et al. 2005; Termaat et al. 2019; Gil-Tapetado et al. 2023).

Selysiothemis nigra (Vander Linden, 1825), the type species of the monotypic genus *Selysiothemis* Ris, 1897 (Odonata: Libellulidae: Urothemistinae), examplifies this pattern of expansion. Its native distribution is scattered yet broadly extends from North Africa and southern Europe through the Middle East to South Asia within the western and central Palearctic (Lohr 2005; Boudot and Kalkman 2015). It ranges from Morocco in the west to Central Asia and China in the east, and from South Asia and the Arabian Peninsula in the south to the southern Urals in the north (Boudot and Kalkman 2015; Smallshire and Swash 2020). Traditionally considered an Iranoeremian faunal element (Uboni et al. 2015; Vilenica et al. 2016), the species occurs in Europe mainly within the Mediterranean Basin, often restricted to coastal areas (Boudot and Kalkman 2015; Kalkman 2020), particularly in Spain, Italy, and the Balkans.

As most of its distribution lies in semi-arid habitats, *S. nigra* is known for its nomadic and migratory behaviour (e.g. Borisov 2005; Smallshire and Swash 2020), enabling individuals to travel far from any resident populations. As a consequence, *S. nigra* frequently occurs far from known breeding sites in low numbers (De Knijf et al. 2013; Uboni et al. 2015), complicating the interpretation of isolated records. However, from the 2000s onward, *S. nigra* has undergone a pronounced northward expansion, clearly distinguishable from these occasional vagrant specimens, prompting numerous reports of the species from countries it has never been observed before (Uboni et al. 2015). For example, it has been documented in Bulgaria (Marinov 2000), Portugal (Lohr 2005), Slovenia (Šalamun 2012), Albania (Murányi and Kovács 2013), Bosnia and Herzegovina (Kulijer et al. 2013), continental France (Lohr 2021), and recently, in Serbia (Đurđević et al. 2024) too.

As part of this ongoing latitudinal range shift, *S. nigra* was recorded in the Carpathian Basin for the first time in 2020, when a single female specimen was captured in Hungary, subsequently published as new to the Hungarian fauna (Mészáros 2020). Based on its colouration and general appearance, the specimen was most likely freshly emerged, suggesting that local reproduction may have occurred in the area prior to the observation. However, no additional individuals were detected during the fieldwork, and no further evidence of a local population had been reported since.

The findings mentioned above were in most cases based on adult individuals, providing little information regarding possible reproduction. To date the northernmost breeding population, supported by evidence of autochthony, had been reported from northeastern Italy, along the northern Adriatic coast (Uboni et al. 2015). On the other hand, by looking at the well-documented expansion, and considering the specimens from Hungary, we can suggest that there likely are autochthonous populations at greater latitudes. Given the migratory character of the species, it is vital to not only keep track of occasional specimens but to take account of breeding populations too. Therefore, our aim in the present study has been to (i) document the occurrences of *S. nigra* in Hungary based on combined field and citizen science data, and (ii) to verify the presence of an established breeding population in the Carpathian Basin at the northern edge of the species' current European range.

Material and methods

During the past five years, we recorded all occurrences of *Selysiothemis nigra* available to us. In addition to our own sporadic observations, we have relied on several citizen science platforms, including thematic Facebook groups (e.g. "Ízeltlábú határozó – lepkék, bogarak, pókok, poloskák, egyéb rovarok és tsai"; https://www.facebook.com/groups/izeltlabuhatarozo/), iNaturalist (https://www.inaturalist.org), and the Hungarian website ízeltlábúak.hu (https://izeltlabuak.hu), a popular platform widely used by amateur entomologists. The use and effectiveness of citizen science for tracking changes in a species' distribution has been widely discussed in the literature (e.g. O'Neill et al. 2023). In particular, records originating from ízeltlábúak.hu have proven important for monitoring the Hungarian entomofauna (e.g. Schlitt et al. 2024; Varga and Horváth 2024; Székely et al. 2025).

To search for naiads, we investigated a site in the outskirts of Dunaharaszti (south of Budapest, Pest county, central Hungary), where numerous copulating adults had previously been observed (Fig. 1, b). Based on these observations, we surveyed the surrounding area to identify potential larval habitats. We examined two adjacent gravel pit ponds located closest to the adult observations (coordinates: 47.3262°N, 19.1251°E for Pond 1 and 47.3253°N, 19.1272°E for Pond 2).

Both ponds are situated in an open, lowland landscape dominated by agricultural fields and are bordered by a narrow belt of trees and shrubs such as *Populus* sp.. The water bodies originated from gravel extraction activities and are characterized by steep shorelines and relatively clear water.

According to satellite imagery, Pond 2 was formed between 2004 and 2008, while Pond 1 was created later, in 2009, as an elongation of Pond 2. The two ponds were subsequently separated by a narrow land bridge. Pond 1 has a surface area of approximately 3.3 ha. Its shoreline is dominated by coarse substrate, consisting mainly of large pebbles and gravel (Fig. 1c). In contrast, Pond 2 currently covers approximately 12 ha and exhibits a similar shoreline structure; however, the substrate at the sampling site is more silted, indicating a higher degree of sediment deposition. Emergent vegetation along the pond margins is dominated by common reed (*Phragmites australis* Trin. ex Steud.), while submerged and floating-leaved macrophytes are largely absent at the sampling locations, resulting in mostly open, unvegetated littoral zones.

Figure 1. Mating adults of *Selysiothemis nigra* photographed in Dunaharaszti (**a, b**), and the sampling point of Pond 1 at the same location where the adults were recorded (**c**). Photographs of the adults by Ferenc Klecska (https://www.izeltlabuak.hu/talalat/545751, CC BY 4.0).

All dragonfly larvae encountered during sampling were collected for identification. Specimens were captured from the littoral substrate alive using a hand net with fine mesh and were placed in Falcon tubes filled with cold water. Sampling was performed by disturbing the bottom substrate and dislodging stones with rubber boots, followed by sieving the resuspended material in the immediate vicinity of the disturbed area. The tubes with the specimens were transported to the laboratory in a cooled state, stored overnight in a refrigerator, and examined on the following day.

Identification of naiads under a stereomicroscope was based on the field guide of Ambrus et al. (2018) and the key by Carchini (1983). Naiads of *S. nigra* can be clearly distinguished from all other odonate larvae occurring in Hungary by the following traits (Fig. 2): the head is triangular, the eyes are small and elongated longitudinally (Fig. 2a), and the abdominal segments bear mid-dorsal spines, except for the 9th segment, which lacks any spine (Fig. 2c).

All collected specimens are preserved in the Collection of Smaller Insect Orders of the Hungarian Natural History Museum Public Collection Centre – Hungarian Natural History Museum, Budapest (HNHM).

Results and discussion

Material examined

Hungary • 1 ♀; Káptalantóti, wet meadow; 46.8539°N, 17.4968°E; 02. Aug. 2020; Csilla Körmendy, Ádám Mészáros, Barnabás Szegedy leg.

Hungary • 1 ♂; Dabas, dry sandy grassland; 47.1768°N, 19.3010°E; 09. Jul. 2021; Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros leg.

Hungary • 1 ♀; Dabas, dry sandy grassland; 47.1528°N, 19.3105°E; 11. Jul. 2021; Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros leg.

Hungary • 1 ♀; Dabas, dry sandy grassland; 47.1562°N, 19.3084°E; 11. Jul. 2021; Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros leg.

Hungary • 1 ♂; Dabas, dry sandy grassland; 47.1605°N, 19.3103°E; 11. Jul. 2021; Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros leg.

Hungary • 1 ♀; Veresegyház, Álomvölgyi tó (lake); 47.6341°N, 19.2680°E; 21. Jun. 2025; Levente Kollár leg.

Hungary • 1 ♀; Budapest, Gőzmozdony utca; 47.4698°N, 19.1578°E; 27. Jun. 2025; Tamás Kollár leg.

Hungary • 5 ♂, 3 ♀; Dunaharaszti, gravel pit lakes; 47.3258°N, 19.1259°E; 24. Jul. 2025; Levente Kollár, Ádám Mészáros leg.

Hungary • 6 naiads; Dunaharaszti, gravel pit lakes; 47.3262°N, 19.1251°E; 19. Oct. 2025; Levente Kollár, Tamás Kollar, Ádám Mészáros, Áron Székely leg.

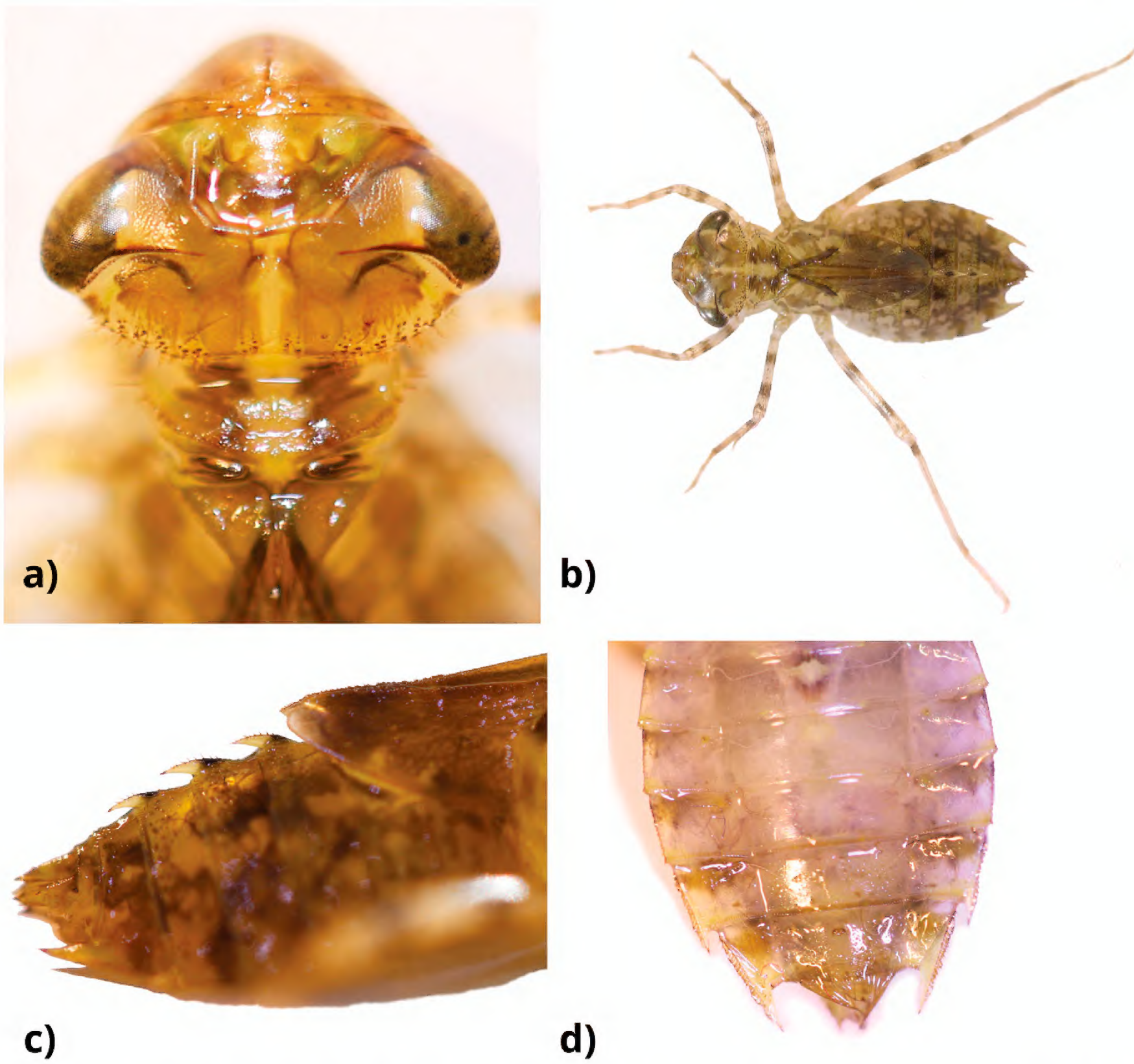

Figure 2. External characteristics of a naiad of *S. nigra* from the autochthonous population of Dunaharaszti: **a.** Head; **b.** Appearance, dorsal view; **c.** Abdominal segments with and without mid-dorsal spines, lateral view; **d.** Abdomen, ventral view. Photos by Málna Pálhegyi.

Hungary • 5 naiads; Dunaharaszti, gravel pit lakes; 47.3253°N, 19.1272°E; 19. Oct. 2025; Levente Kollár, Tamás Kollár, Ádám Mészáros, Áron Székely leg.

The examined individuals were identified as *S. nigra* based on external characteristics. The 39 new occurrences are listed in Appendix 1, while the corresponding locations are shown in Fig. 3.

Since 2020, progressively more specimens have been observed in Hungary each year (Fig. 4). In the first three years, only three sightings were made, all around Lake Balaton; in 2023 and 2024, six sightings were reported in each year. Up to this point, all observations involved single individuals, meaning that each of the 15 records represented a different locality.

In 2025, however, the situation changed drastically: we recorded 25 sightings, exceeding the total of all earlier years combined, including six observations of 10 or more individuals at a single site. Among these, three observations stand out involving swarms of over 100 individuals at once (based on estimation). Although precise counting was not possible, such numbers are not unusual for this species, as swarming behaviour is well documented in the literature (e.g. Schneider 1981; Holuša 2011) and is associated with the migratory character of the species.

On 19 October 2025, a total of 11 naiads of *S. nigra* were found at the Dunaharaszti gravel pits. We found six naiads in Pond 1 and five in Pond 2; other odonate species collected at the site included *Crocothemis erythraea* (Brullé, 1832), *Anax imperator* Leach, 1815 / *A. parthenope* (Sélys, 1839), *Orthetrum cancellatum* (Linnaeus, 1758) / *O. albistylum* (Sélys, 1848), and *Ischnura elegans* (Vander Linden, 1820).

The presence of *S. nigra* at Dunaharaszti had already been confirmed by observations of adults, with the first sighting recorded in 2024. The next year, slightly more than two and a half months before the discovery of the naiads, multiple mating adults were observed (Fig. 1a, b). The continuous presence of adults over at least two consecutive years, combined with the observation of mating adults and direct evidence of successful reproduction confirms that an established population is present at this site. Previously, the northernmost breeding of the species was reported by Uboni et al. (2015) from northern Italy at the latitude of 45.8764°N. Our record at 47.3262°N therefore represents the northernmost autochthonous population in the world known to date, and simultaneously the first established population documented in the Carpathian Basin.

A second population may exist in the Balaton Uplands, given that the earliest Hungarian records originated from that region. Notably, the gravel pit lakes near Salföld are located close to these records and are very similar in character to the Dunaharaszti site, suggesting that a

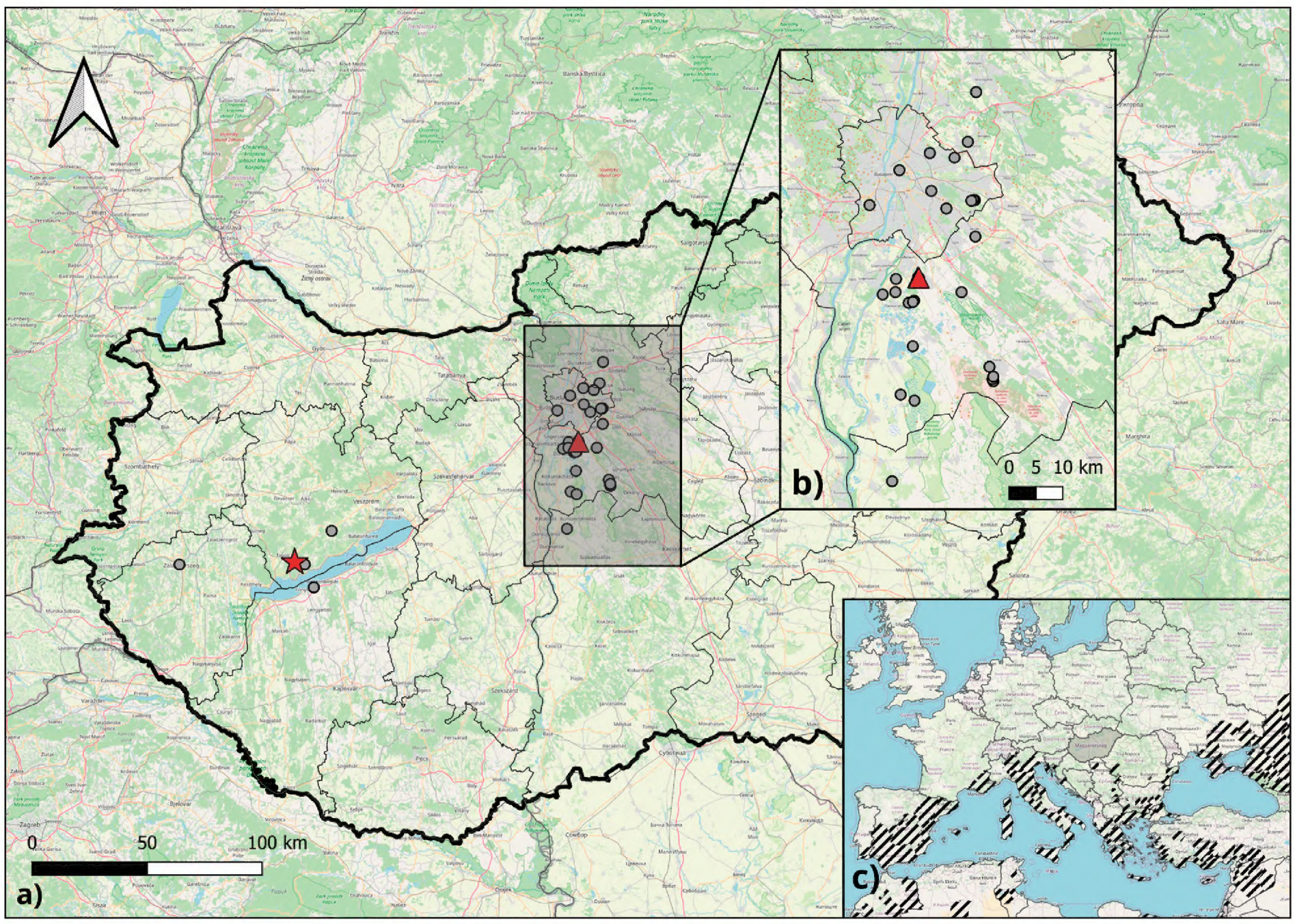

Figure 3. Occurrences of *Selysiothemis nigra* in Hungary from 2020 (**a**), with the records from the Danube-Tisza Interfluve enlarged (**b**). Published data of Mészáros (2020) is marked with a red asterisk, records of naiads are marked with a red triangle, while the grey dots represent observations of adult specimens. The European distribution without Hungary is shown as a hashed area based on the GBIF database (GBIF.org 2025), with additional records from Moali and Durand (2015) and Lohr (2021) (**c**).

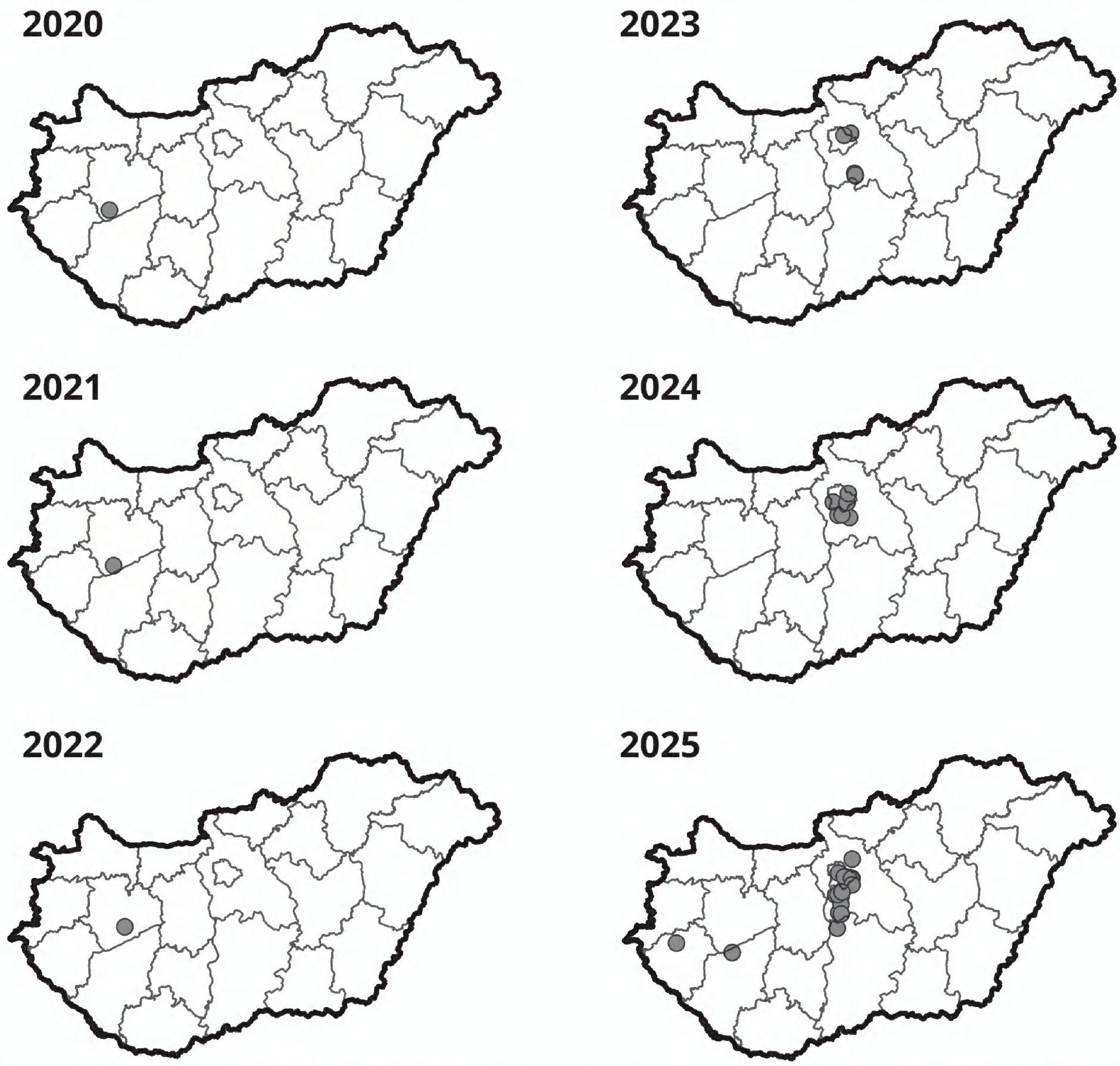

Figure 4. Annual observations of *Selysiothemis nigra* in Hungary between 2020 and 2025. The record from 2020 is published in Mészáros (2020).

local population could have developed there as well in the early 2020s, potentially serving as the source of some of the observed individuals. However, further evidence is needed to confirm this, as no swarming, mating pairs, or naiads have yet been documented there.

These results are consistent with the species' ongoing northward expansion. However, the available evidence supporting this process is often based solely on adult individuals, as is commonly the case in studies reporting records from new countries (e.g. Koren et al. 2012; Kulijer et al. 2013; Martynov 2020). Reports of reproduction or establishment remain scarce (Uboni et al. 2015) and are mostly limited to Mediterranean regions (e.g. De Knijf et al. 2013; Vilenica et al. 2016). Due to the migratory and nomadic character of *S. nigra*, it is important to distinguish sporadic specimens from actual breeding populations, as the latter provides more reliable information about the true extent of the species' reproduction.

Speculating about the route of the expansion, Đurđević et al. (2024) suggested that *S. nigra* (alongside another Mediterranean dragonfly, *Trithemis annulata* (Palisot de Beauvois, 1807)) likely "utilized existing river corridors through Serbia to colonize new sites", i.e. spread further along the Morava–Danube–Tisza rivers. Schneider (1981) also noted that linear structures could facilitate migratory routes of *S. nigra*. Although the first Hungarian records were made away from these rivers, near Lake Balaton, most of the subsequent observations (including the confirmed autochthonous population) come from the Danube–Tisza Interfluve which could have been reached by following the river corridors mentioned above.

There are two major explanations in the literature for the drivers of the expansion of the Black Pennant: the formation of numerous artificial water bodies and the effect of climate change (Boudot and Kalkman 2015; Lohr 2021; Đurđević et al. 2024). Compte Sart (1960) suggested that

the 25 °C July isotherm may represent the northern limit of the species' distribution, implying that recent warming could be facilitating its northward shift. On the contrary, Martynov et al. (2015) argued that artificial habitats play a bigger role, noting that the species expanded its range in the Sea of Azov region during a period of decreasing average annual temperatures. In our study, *S. nigra* was found predominantly in and around artificial lakes rather than in the ephemeral waters typically used for reproduction in the Mediterranean region, consistent with the description by Kalkman (2020). On the other hand, satellite imagery indicates that most of these ponds situated in the area were created between 2005 and 2010, i.e. more than a decade before the first record of the species in Hungary. This could suggest that climatic factors may be more influential than habitat availability in driving the expansion of *S. nigra* in the Carpathian Basin, though the specific climatic variables involved require further investigation.

It is also noteworthy that *S. nigra* is not the first odonate species of southern origin currently expanding its range, that was recently added to the fauna of Hungary: Móra and Farkas (2015) reported an established population of the Holomediterranean *Erythromma lindenii* (Selys, 1840) in southeastern Hungary, and a single specimen of *Trithemis annulata* was photographed in the south of the country near Pécs (Farkas 2017). The spread of the latter has been strongly linked to warming climate (Boudot and Kalkman 2015; La Porta and Handersen 2024), and it remains uncertain whether the species will establish breeding populations in the area. The Mediterranean *Trithemis arteriosa* (Burmeister, 1839) has also been recorded in Hungary in the recent years by a single occurence (Móra and Sebteoui 2020), likely facilitated by aquarium trade.

A large source of the dataset documenting the spread and establishment of *Selysiothemis nigra* in the Carpathian Basin (Appendix 1) originated from citizen science platforms. Monitoring such distributional changes is essential for understanding species ecology and the factors shaping range limits (Sexton et al. 2009), achievable better by constant monitoring of a large area, striving to reduce spatial gaps for which citizen science can be used with great success (Callaghan et al. 2021). We therefore emphasize the value of integrating citizen science data with targeted field investigations to effectively track ongoing and potentially accelerating shifts in species distributions.

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Appendix 1

Table A1. Observations of *Selysiothemis nigra* (Vander Linden, 1825) from Hungary until the end of 2025 in alphabetical order by settlement name. For each new record, the following information is provided: locality (settlement name and geographical coordinates, given to four decimal places), date of observation, information on the individuals (number, sex, and life stage (N = naiad, none = adult)), and the name of the collector or photographer. Specimens preserved in the Hungarian Natural History Museum are marked with (*). Previously published data from Mészáros (2020) is marked with (**).

Locality	Observations
Apaj [47.1304°N, 19.0818°E]	21.VI.2025, 1 ♂, Vojtěch Vyskočil
Apaj [47.1204°N, 19.1163°E]	19.VIII.2025, 1 ♀, István Emri
Budapest [47.5331°N, 19.1543°E]	4.VIII.2023, 1 ♀, Edit Horváth
Budapest [47.4463°N, 19.0054°E]	26.VI.2024, 1 ♂, Barnabás Montvai
Budapest [47.4406°N, 19.1946°E]	5.VII.2024, 1 ♀, Barnabás Montvai
Budapest [47.5253°N, 19.2148°E]	7.VII.2024, 1 ♀, Csaba Schmidt
Budapest [47.4544°N, 19.2645°E]	23.VI.2025, 1 ♀, Károly Diószegi
Budapest [47.4698°N, 19.1578°E]	27.VI.2025, 1 ♀*, Tamás Kollár
Budapest [47.5043°N, 19.0788°E]	27.VI.2025, 1 ♀, Levente Horváth
Budapest [47.4544°N, 19.2645°E]	4.VII.2025, 1 ♂, Károly Diószegi
Budapest [47.4547°N, 19.2612°E]	11.VII.2025, 1 ♂, Tamás Soós
Budapest [47.4535°N, 19.2564°E]	19.VII.2025, 3 ♂♀, Zoltán Bebesi
Bugyi [47.2860°N, 19.1132°E]	5.VII.2025, approx. 100 ♂♀, Csaba Zsoldos, Judit Pethő
Bugyi [47.2873°N, 19.1155°E]	6.VII.2025, approx. 100 ♂♀, Zoltán Bebesi, Csaba Zsoldos, Judit Pethő, Csaba Schmidt
Bugyi [47.2851°N, 19.1123°E]	6.VII.2025, approx. 100 ♂♀, Csaba Zsoldos, Zoltán Bebesi, Judit Pethő, Csaba Schmidt
Csömör [47.5517°N, 19.2477°E]	7.VII.2023, 1 ♂, Péter Ruttkai
Dabas [47.1768°N, 19.3010°E]	9.VII.2023, 1 ♂*, Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros
Dabas [47.1528°N, 19.3105°E]	11.VII.2023, 1 ♀*, Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros
Dabas [47.1562°N, 19.3084°E]	11.VII.2023, 1 ♀*, Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros
Dabas [47.1605°N, 19.3103°E]	11.VII.2023, 1 ♂*, Botond Balogh, Máté Bernát, Áron Horváth, Áron Székely, Nimród Varga, Ádám Mészáros
Dunaharaszti [47.3258°N, 19.1263°E]	30.VI.2024, 1 ♀, Ferenc Klecska
Dunaharaszti [47.3258°N, 19.1263°E]	19.VII.2025, approx. 20 ♂♀, Ferenc Klecska
Dunaharaszti [47.3258°N, 19.1259°E]	24.VII.2025, approx. 30 ♂♀*, Levente Kollár, Ádám Mészáros
Dunaharaszti [47.3262°N, 19.1251°E]	19.X.2025, 6 N*, Ádám Mészáros, Áron Székely, Levente Kollár, Tamás Kollár
Dunaharaszti [47.3253°N, 19.1272°E]	19.X.2025, 5 N*, Ádám Mészáros, Áron Székely, Levente Kollár, Tamás Kollár
Dunavarsány [47.2835°N, 19.1018°E]	5.VII.2025, 3 ♂, Csaba Zsoldos, Judit Pethő
Dunavarsány [47.2975°N, 19.0378°E]	6.VII.2025, approx. 10 ♂♀, Csaba Zsoldos, Judit Pethő
Dunavarsány [47.3014°N, 19.0691°E]	27.IX.2025, 1 ♀, Csaba Zsoldos
Káptalantóti [46.8539°N, 17.4968°E]	2.VIII.2020, 1 ♀**, Csilla Körmendy, Ádám Mészáros, Barnabás Szegedy
Kékkút [46.8450°N, 17.5550°E]	29.VII.2021, 1 ♂, Attila Szabó
Kiskunlacháza [47.2113°N, 19.1122°E]	19.VII.2025, 1 ♂, Attila Steiner
Ócsa [47.3013°N, 19.2322°E]	26.VI.2024, 1 ♀, Sándor Farkas
Ordacsehi [46.7544°N, 17.6063°E]	24.VI.2025, 1 ♂, “megyek mindenfele”
Ordacsehi [46.7544°N, 17.6063°E]	31.VII.2025, 1 ♂, “megyek mindenfele”
Taksony [47.3234°N, 19.0706°E]	17.VI.2024, 1 ♀, Ábris Tóth
Tass [46.9853°N, 19.0610°E]	2.VII.2025, 1 ♂, Tibor Danyik
Vecsés [47.3938°N, 19.2662°E]	25.VII.2025, 1 ♀, Csaba Schmidt
Veresegyház [47.6341°N, 19.2680°E]	21.VI.2025, 1 ♀*, Levente Kollár
Vöröstó [46.9770°N, 17.7092°E]	25.VII.2022, 1 ♂, Sándor Farkas
Zalaegerszeg [46.8445°N, 16.8353°E]	17.VI.2025, 1 ♂, “mothdragon”